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GENERAL DYNAMICS | CONVAIR

Report No. 8926-133

Material - Finishes and Coatings - Wear Preventative for Aluminum and Titanium

Comparative Wear Resistance

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Comparative Wear Resistance

Abstract:

The wear resistance of twenty-five different finish coatings applied on 7075-T6 aluminum alloy and AMS 4925 titanium alloy was tested with wear couples incorporating either coated aluminum or titanium alloy and chrome plated 4130 steel. Comparisons of individual test results were made by reference to tests made with chrome plated 4130 steel and Specification MIL-B-6946 bronze. All tests were made with a Timken wear test machine. Nitrided and molybdenum spray coatings applied to titanium, and hard anodize or chrome plate applied to aluminum provided better wear resistances in couples lubricated with Specification MIL-L-7870 lubricating oil than similarly lubricated chrome plated steel-bronze wear couples. Electrofilm 4396 solid film dry lubricant provided the greatest wear life of all such lubricants tested. Five hundred hours of salt spray impingement produced no corrosive effects on titanium. Two hundred fifty hours of salt spray resulted in no corrosion of hard anodized or Electrofilm 4396 coated 7075-T6 bare aluminum; however, only Electrofilm 4396 withstood the salt spray impingement when 7075-T6 clad aluminum was tested. Nitrited titanium surfaces adhered well in material subjected to tension, but was poor in compressed material. Chrome plated titanium and aluminum withstood both tensile and compressive deformations. Hard anodized aluminum behaved well in tension, but was poor in compression. Supplementary tests with anodized titanium indicated the better performance, among anodic coatings, of a proprietary "tri-oxide" process.

Reference: 1. Barlow, R. J., Vollmecke, A. R., Wise, W. E., "Wear Test of Surface Treatments on Aluminum Alloy and Titanium Alloy," General Dynamics/Convair Report S.L. 56-64, San Diego, California, 26 April 1957, (Reference attached).

2. Barlow, R. J., Vollmecke, A. R., Wise, W. E., "Wear Test of Anodic Treatment on Titanium," General Dynamics/Convair Report S.L. 56-64, Add. I, San Diego, California, [illegible] 1958, (Reference attached).

CONVAIR

A DIVISION OF GENERAL DYNAMICS CORPORATION

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ENGINEERING TEST LABORATORIES

REPORT 56-64

DATE 4-26-57

MODEL ALL

(REA 7634)

TITLE

REPORT NO. 56-64
WEAR TEST OF SURFACE TREATMENTS ON
ALUMINUM ALLOY AND TITANIUM ALLOY

MODEL ALL
(REA 7634)

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A	8-19-58	Wise	Table I and Table III corrected	8 and 10

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REPORT NO. 56-64
WEAR TEST OF SURFACE TREATMENTS ON ALUMINUM ALLOY AND TITANIUM ALLOY

REFERENCE:

(a) Convair Test Report No. 56-212 - "Corrosion Inhibitive Properties of Various Coatings of Solid Film Lubricants" September 10, 1956.

INTRODUCTION:

This test was undertaken to find a coating or a surface treatment for aluminum and titanium which would be suitable as a friction bearing surface.

OBJECT:

A. To compare the wear performance characteristics of treated aluminum and titanium surfaces rubbing on chrome molybdenum steel to a standard of bronze rubbing on chrome plated chrome molybdenum steel.

B. To determine the corrosive effects of 250 hours of salt spray exposure on specimens having surface conditions identical to wear test specimens.

C. To determine the adhesion of the surface treatments on specimens identical to those in part "B".

CONCLUSION:

A. Wear Test:

Two titanium surface treatments produced greater wear resistance surfaces than the bronze standard. These were a nitrided surface and a molybdenum spray coating. Hard anodize or chrome plate on 7075-T6 aluminum also produced greater wear resistance than the standard.

Chrome plating by the Chrome-ite process showed superior wear resistance when bearing pressures were in the lower portion of the base material elastic region.

CONCLUSION: (Cont'd.)

A. Wear Test: (Cont'd.)

Electrofilm 4396 as applied per Convair Specification 0-05000 had the greatest wear life of all the solid film lubricants tested.

An experimental room temperature catalyzing resin produced an unsatisfactory solid lubricant bond.

B. Corrosion Tests:

500 hours of salt spray exposure had no corrosive effects on any of the titanium specimens. 250 hours of salt spray exposure had no corrosive effects on bare 7075-T6 aluminum coated with either hard anodize or Electrofilm 4396C. On clad 7075-T6 aluminum, only Electrofilm 4396C withstood exposure without evidence of corrosion.

C. Adhesion:

The nitrided titanium surface had good adhesion when the treated surface was subjected to a tensile force longitudinally, but poor when subjected to a compressive force longitudinally.

Chrome plate on titanium by the Chrome-ite process produced a coating with very good adhesion when subjected to either longitudinal compression or tension.

Hard anodize had good adhesion on aluminum. Adhesion was greater to a surface in tension than to a surface in compression; it was also greater for a clad aluminum alloy surface than for a bare aluminum alloy surface.

TEST SPECIMENS:

The test equipment consisted of a modified Timken machine and test cups similar to Timken Test Cup T-54148. A sketch of the test cup is shown in Figure 3. The outside diameter of these test cups had a 63 RMS or a 16 RMS finish surface, on which a treatment was applied.

Test cups consisted of the following materials:

1. Bronze, Specification MIL-B-6946 with a 16 RMS finish.

2. Titanium, AMS 4925 with the following surface treatments:

2.1 Untreated

2.2 Electrofilm 4396 on a 63 RMS finish per Convair Specification No.0-05000 by National Plating & Processing Company, National City, California.

TEST SPECIMENS: (Cont'd.)

2.3 Nitride per Convair Specification Standard Q1837 on a 16 RMS finish by Convair San Diego, California.

2.4 Anodic treatment sesqui-oxide on a 63 RMS finish by Chem-Tronics Laboratory, San Diego, California.

2.5 Sesqui-Lube, a solid film lubricant over sesqui-oxide on a 63 RMS finish by Chem-Tronics Laboratory, San Diego, California.

2.6 Electrofilm 4396 over sesqui-oxide on a 16 RMS finish by National Plating and Processing, National City, California.

2.7 Electrofilm 4396C over sesqui-oxide on a 16 RMS finish by National Plating and Processing, National City, California.

2.8 Chrome Plate without grinding on a 16 RMS finish. The Chrome-ite Process by Persson Tool and Die Service, Los Angeles, California.

2.9 Molybdenum spray by Metalizing Co. of Los Angeles and ground to a .010 ± .001 thickness by Convair - San Diego.

2.10 Nickel Plate .001 ± .0002 per Convair Specification 0-05009 on a 16 RMS finish by Chemplate Corporation, Los Angeles 58, California.

2.11 L-FN-530 treatment on a 16 RMS finish by American Chemical and Paint Company.

2.12 Solid film lubricant (Epon 828-20 gm., Riyamide #125-10 gm., and Molykote 75 gm.) experimental room temperature catalyzing resin on a 16 RMS finish by Convair Test Laboratories.

2.13 Teflon coating on a 16 RMS finish per Specification FPS-0004 with the exception of a sesqui-oxide undercoat by Chem-Tronics Laboratories, San Diego, California.

2.14 Nylon coating per Dupont Bulletin, "Zytel-Nylon Resin" on a 16 RMS finish applied by Convair, San Diego, California.

2.15 Molykote solid film lubricant (1 coat of X107 and 1 coat of X106) on 16 RMS finish by Convair, San Diego, California.

3. Aluminum 7075-T6, Specification QQ-A-277 with the following surface treatments:

3.1 Bare with a 20 RMS finish.

TEST SPECIMENS: (CONT'D.)

3.2 Nickel Plate .001 $\pm$ .0005 thick per Convair Specification 0-05009 by Langley Company, San Diego, California.

3.3 Hard anodize, Alcoa process X-226, on a 50 RMS finish by the Sanford Process Co., Inc., Los Angeles.

3.4 Electrofilm No. 4396 on a 50 RMS finish per Convair Specification No. 0-05000 by National Plating and Processing Company, National City, California.

3.5 Electrofilm No. 4396C, .0012 inches thick, on a 16 RMS finish by the Convair-San Diego Test Laboratories.

3.6 Electrofilm No. 4396C, .0008 inches thick, on a 16 RMS finish by Convair-San Diego, California, Test Laboratories.

3.7 Electrofilm 4396C, .00075 inches thick, on a 16 RMS finish by the Convair-San Diego Test Laboratories.

3.8 Electrofilm 4396C per Electrofilm specifications, by National Plating and Processing Company, National City, California.

3.9 Stainless steel spray by Metalizing Company of Los Angeles, California. These specimens were ground to a .002 $\pm$ .0005 thickness with a 16 RMS finish by Convair-San Diego.

3.10 Molybdenum spray by Metalizing Company of Los Angeles and ground to a .002 $\pm$ .0005 thickness with a 16 RMS finish by Convair - San Diego.

3.11 Chrome plate per Specification QQ-C-320 Class 2 by Langley Corp., San Diego, and ground to a .001 $^{+.001}_{-.000}$ thickness with a 16 RMS finish by Convair, San Diego.

Adhesion and corrosion specimens were made for each of the surface treatments listed for aluminum and titanium wear specimens. The specimens were 2 x 8 inch rectangles cut from .040 thick sheet stock. The materials were titanium AMS 4908 and aluminum 7075-T6.

TEST PROCEDURE:

A. Wear Tests:

Testing was conducted with a modified Timken machine at 70 R.P.M. This produced a sliding velocity of 25.2 feet per minute. A chrome-moly steel block, with RC55-60 surface hardness to a depth of .020 inches, applied the bearing pressure. Upon rotation of the cup, sliding took place between the outside diameter of the cup and the stationary block. A typical test set-up is shown in Figure 6.

TEST PROCEDURE: (Cont'd.)

A. Wear Tests: (Cont'd.)

Solid film lubricants, such as Electrofilm and Sesqui-lube, were tested dry. All other tests had liquid lubrication. This was accomplished by rotating the cup in a sump of lubricating oil Specification MIL-L-7870 during the test operation.

The performance of bronze cups rubbing on a chrome plated steel block was obtained for a comparative standard.

Testing consisted of the following phases:

1) 2 hours at 5,000 psi
2) 1 hour at 40,000 psi
3) 1/2 hour at 80,000 psi

In some cases the specimen was tested beyond the one half hour time limit for the 80,000 psi phase. The time limit for the first and second phase was not extended. These test phases were applied to all specimens except for the teflon and nylon coatings.

Testing for all specimens terminated at the time of failure except bare aluminum, bronze, nitrided titanium, and molybdenum-sprayed titanium. Tests of the unfailed specimens were terminated in the third phase at the time that their wear life had greatly exceeded that of the bronze standard.

A failure is defined as any one of the following:

1. A 25 percent increase in friction over normal running friction. (This friction increase would activate a preset switch causing the test machine to shut-off automatically).

2. An abnormal increase of either frictional force or temperature.

3. The exposure of untreated or bare surfaces in the case of the coatings or surface treatments.

4. Bond failure of the solid film lubricant.

B. Corrosion:

Corrosion testing was in accordance with reference (a), a standard salt spray exposure test.

C. Adhesion:

The scrape test, as shown in Figure 4, and the bend test, as shown in figure 5 were used to determine the adhesion of coating and surface treatments.

RESULTS:

A. Wear Test:

The results are shown in graphic form in Figures 1 and 2. At the top of each chart are wear characteristics of a bronze cup rubbing on a chrome plated steel block. This serves as a comparative standard for other bearing material performance.

Figures 1 and 2 are composed of averages of two specimens.

For tabulated discussion of results see Table VII.

B. Corrosion Test:

The results are shown in Tables I, II, and III. The panel numbers correspond to the test cups listed under Test Specimen and Figures 1 and 2.

C. Adhesion Tests:

The results are shown in Tables IV, V, and VI. The specimen numbers correspond to those listed under Test Specimen and Figures 8, 9, 10, and 11 of this report.

NOTE:

The test data from which this report was prepared are recorded in Engineering Test Laboratories Data Book No. 393.

FIGURE INDEX

TABLE I

CLAD 7075-T6 ALUMINUM ALLOY WITH VARIOUS COATING AFTER 250 HOURS SALT SPRAY EXPOSURE

PANEL NO.	HOURS EXPOSURE								RELATIVE RATING
	25	50	75	100	175	200	225	250	(Visual)
3.1	10	10	10	10	10	10	9	9	2=
3.2	8	6	6	5	4	3	3	3	3
3.3	10	10	10	10	10	10	9	9	2=
3.11	6	5	5	4	3	0	0	0	5
3.9	4	2	0	0	0	0	0	0	7
3.10	3	2	1	1	1	0	0	0	6
3.4	7	5	5	3	2	2	2	2	4=
3.5-3.8	10	10	10	10	10	10	10	10	1

Note: 0 = Complete Corrosion
4 = Severe Corrosion
6 = Moderate Corrosion
10 = No Corrosion

Note: = indicates 2 or more specimens of the same relative rating.

See test specimen section of this report for surface treatments.

TABLE II

BARE 7075-T6 ALUMINUM ALLOY WITH VARIOUS COATINGS AFTER 250 HOURS SALT SPRAY EXPOSURE

Panel No.	Hours Exposure								Relative Rating
	25	50	75	100	175	200	225	250	(visual)
3.1	9	9	9	7	5	5	4	4	3=
3.2	8	7	6	5	3	2	2	1	4
3.3	10	10	10	10	10	10	10	10	1=
3.11	7	7	6	4	4	4	4	4	3=
3.9	6	4	3	2	0	0	0	0	7
3.10	5	5	4	4	2	0	0	0	5
3.4	6	4	4	3	2	0	0	0	6
3.5-3.8	10	10	10	10	10	10	10	10	1=
3.12	9	9	9	6	5	5	5	5	2

Note: 0 = Complete Corrosion
4 = Severe Corrosion
6 = Moderate Corrosion
10 = No Corrosion

Note: = indicates 2 or more specimens of the same relative rating.

See test specimen section of this report for surface treatments.

TABLE III

AMS 4908 TITANIUM WITH VARIOUS SURFACE COATING AFTER 500 HOURS SALT SPRAY EXPOSURE

PANEL NO.	HOURS EXPOSURE							
	25	50	75	100	175	200	225	500
2.1				No Corrosion				10
2.2				No Corrosion				10
2.3				No Corrosion				10
2.4				No Corrosion				10
2.5				No Corrosion				10
2.6				No Corrosion				10
2.7				No Corrosion				10
2.8				No Corrosion				10
2.9				No Corrosion				10
2.10				No Corrosion				10
2.11				No Corrosion				10
2.12				No Corrosion				10
2.13				No Corrosion				10
2.14				No Corrosion				10
2.15				No Corrosion				10

Note: See test specimen section for surface treatments.

TABLE IV
ADHESION TEST

Surface Treatments On AMS 4925 Titanium	Bend Test		Scrape Test
	Angle At 1st Failure	Observation at 90° Bend	
2.1		No Test	
2.2 Electrofilm 4396	None	No Change	Burnished OK
2.3 Nitride		80% of inside radius flaked off-few specks flaked at outside radius edges.	None
2.4 Sesqui-Oxide	None	No Change	None
2.5 Sesqui-Lube	None	No Change	Burnished OK
2.6 Electrofilm 4396 over Sesqui-Oxide	None	No Change	Burnished OK
2.7 Electrofilm 4396C over Sesqui-Oxide	None	No Change	Burnished OK
2.8 Chrome-ite	None	Specimen failed at 450 bend. Coating showed no signs of any change.	None
2.9 Molybdenum Spray	45°	Coating cracks heard at 450 bend. Coating crack on outside radius. Flaking on inside radius. Bond failure between coats.	None
2.10 Nickel Plate	85°	Slight flaking on edges of outside. Plating crimped and flaking on crimp lines.	None
2.11 L-FN-530	None	No Change	None
2.12 Solid Film by Convair	None	No Change	Coating scraped thru in 140 stroke
2.13 Teflon Over Sesqui-Oxide	None	No Change	High points wore thru in 10 strokes
2.14 Nylon	None	No Change	23 Strokes
2.15 Molykote X107	None	No Change	Chipping in 20 strokes

TABLE V

ADHESION TEST

Surface Treatments on 7075-T6 Aluminum (Clad)	Bend Test		Scrape Test
	Angle At 1st Failure	Observation at 90° Bend	
3.1 Bare	None	None	None
3.2 Nickel Plate	45°	Parallel crack lines on outside radius with some bond failure at ends-few isolated bond failures on inside radius.	None
3.3 Hard Anodize	None	No effect on outside-few chips,specks, on inside radius.	None
3.4 Electrofilm 4396	None	No Change	Burnished
3.5 Electrofilm 4396C	70°	Minor chipping on outside radius, no change on inside radius.	Burnished
3.6, 3.7 Electrofilm 4396C	20°	Intire inside and outside radius areas peeled off.	Scraped off
3.8		Not tested	
3.9 Stainless Steel Spray	20°	Irregular 1/16 cracks over entire outside radius surface.	None
3.10 Molybdenum Spray	25°	Fine irregular crack on outside radius - crimping and flaking lines on the inside radius surface.	None
3.11 Chrome	60°	Microscopic crack on outside radius surface - crimped plating on inside radius surface.	None
3.12		No Change	Scrapes clean in one stroke
		NOTE Original Specimen Clad Aluminum	

TABLE VI
ADHESIVE TEST

Surface Treatments On Bare 7075-T6 Aluminum	Bend Test		Scrape Test
	Angle at 1st Failure	Observations at 90° Bend	
3.1 Bare		No Test	
3.2 Nickel Plate	45°	Cracking noise heard at 45° - Nearly straight line cracks at .020 inches apart on outside radius.	None
3.3 Hard Anodize	None	20% of inside radius surface chipped - 2 small chip specks on edge of outside radius surface.	None
3.4 Electrofilm 4396	None	No Change	Burnished OK
3.5 Electrofilm	None	No Change	
3.6 Electrofilm	None	No Change	
3.7 Electrofilm	None	No Change	
3.8 Electrofilm 4396C by Nat'l. Plate	None	No Change	Burnished OK
3.9 Stainless Steel Spray	30°	Very small crack lines on outside radius surface. Coating cracked and sealed on inside radius surface. Bond failure between spray coats.	None
3.10 Molybdenum Spray	35°	Coat flowed to one large break line on inside radius. Cracks on outside radius have scale-like finish.	None
3.11 Chrome Plate	None	Extra fine crack lines on outside radius.	None
3.12 Nylon	None	No Change	3 stroke to failure

NOTE

Original Specimen
Bare Aluminum

TABLE VII
TITANIUM SPECIMENS

Specimen No.	General Observation	Friction	Block Temperature	Failure
2.1	Wear more rapid and erratic than aluminum or bronze.	Greater and more erratic than for aluminum and bronze.	Constant	Seizure between cup and block.
2.2	Relatively large volume of solid film lubricant migrated from high points to low areas.	At 5000 psi, increased to a plateau and then remained constant to end of phase. At 40,000 psi, decreased from initial value to a steady state condition. At 80,000 psi, continuous decrease from start to failure.	At 5000 psi increased to a constant value. At 40,000 psi decreased to a steady state. At 80,000 psi continuous decrease.	Seizure.
2.3	No noticeable wear at failure.	At 5000 psi, stabilized in 5 minutes to constant value. At 40,000 psi, decreased. At 80,000 psi, established a plateau in 15 to 30 minutes then remained to end of phase.	At 5000 psi increased to a constant within a few minutes.	Seizure for one specimen, no failure for the other
2.4	Some wear improvement on the surface to .0005 inch depth.	Less erratic than for untreated. At 5000 psi one decreased slightly while the other remained constant. At 40,000 psi, increased slightly during phase.	A general trend of decreasing temperature.	No distinct point. Rate of wear increased.
2.5	Softer film than Electrofilm 4396.	Low initial friction increased to a constant value.	Increased to a constant value.	Lubricant loss, then seizure.
2.6	Surface burnished quickly.	Increased within 10 minutes to a constant which persisted to end of test.	Increased to a constant value within 10 minutes.	Seizure.
2.7	Bearing area not completely burnished, chipping and peeling noted.	Increased to a constant.	Increased to a constant value.	Seizure.
2.8	Wore groove in block.	Increased within 5 minutes to a constant.	Increased to a constant value.	Scraping off of the coating at the edge of the groove in the block.
2.9	Very slight wear to coating at failure, groove .090 to .085 inch wide with 8 RMS finish worn in block.	At 5000 psi constant-groove in block At 40,000 psi slight increase during phase. At 80,000 psi some fluctuations had been experienced.	Constant. A gradual increase. A gradual increase.	No failure.
2.10	Slight wear at failure	Constant during both phases.	At 5000 psi, constant. At 40,000 psi continuously increasing.	Bond failure.

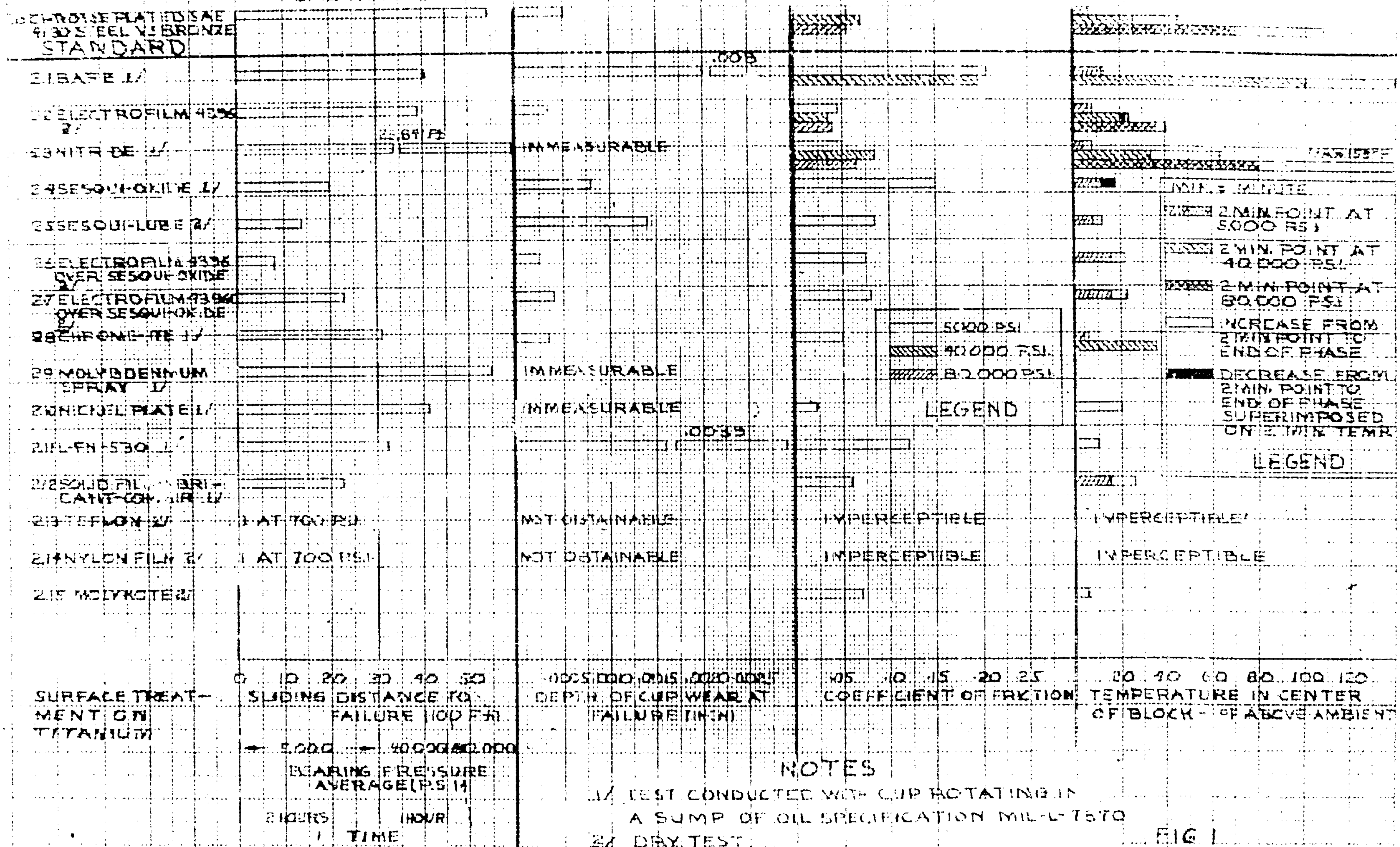
TABLE VII (Cont'd.)
TITANIUM SPECIMEN

Specimen No.	General Observation	Friction	Block Temperature	Failure
2.11	Smoother wear than for untreated. Visible coating worn in one minute.	At 5000 psi, constant.	At 5000 psi established constant within 5 minutes.	No distinct point. Wear resistance decreased gradually to that of untreated material.
		At 40,000 psi, gradual increase	At 40,000 psi continuously increasing.	
2.12	Burnished completely and rapidly.	Friction very low.	Experienced both constant and gradually increasing temperature.	Bond failure.
2.13	Failed within 20 revolutions.		Imperceptable.	Immediate penetration of titanium peaks.
2.14	Failed within 20 revolutions.		Imperceptable.	Immediate penetration of titanium peaks.
2.15	Failed within 20 revolutions.		Imperceptable.	Immediate penetration of titanium peaks.
3.1	Cup wear marks coarser than block finish.	At 5000 psi decreased to a constant value.	At 5000 psi-increased to a constant then increased continuously for 40,000 psi and 80,000 psi.	No failure.
		At 40,000 psi and 80,000 psi—constant		
3.2	Very little wear to the plating.	Initial friction nearly twice the shown value.	Increased continuously.	Bonding failed, the plating blistered and peeled off.
3.3	Grooves worn in the block resembled extra fine threads and matched the parallel machine marks on the cup. Sharpness of the wear markings at the peaks and intersections indicated no wear.	At 5000 psi—constant.	Increased continuously, for all three pressures.	Coating chipped off.
		At 40,000 psi-both constant and increasing		
		At 80,000 psi-increasing friction.		
3.4	Solid film lubricant migrated from the high areas to the depressions.	At 5000 psi increased to a constant.	Increased to a constant value for all three phases.	Line of seizure becoming progressively greater.
		Constant at 40,000 & 80,000 psi.		
3.5	Coating partially burnished.	Constant after a short period of stabilization.	Constant after a short period of stabilization.	Bond failure.
3.6	Coating partially burnished.	Constant after a short period of stabilization.	Constant after a short period of stabilization.	Bond failure.
3.7	Coating partially burnished.	Constant after a short period of stabilization.	Constant after a short period of stabilization.	Bond failure.
3.8	Complete burnishing, harder coating than 3.4.	Constant value.	Remained constant after a period of build-up.	Bond failure.
3.9		Failed within 20 revolutions.	Indeterminate.	Cup coating adhered to the block. Adhered particles created furrows in the coating.

TABLE VII (Cont'd.)
TITANIUM SPECIMEN

Specimen No.	General Observation	Friction	Block Temperature	Failure
3.10	Ring smoothness increased, some block wear did occur.	At 5000 psi-constant.	At 5000 psi-constant.	Bond failure.
		At 40,000 psi-increased the first 15 minutes, then decreased.	At 40,000 psi-increased continuously.	
3.11	Minor wear to chrome plate.	At 5000 psi-scatter between .067 to .025.	At 5000 psi-increased to a constant value in 5 minutes.	Chipping of coating.
		At 40,000 psi-average decrease of .020 for 2 specimens.	At 40,000 psi-increased continuously.	
		At 80,000 psi-constant.	At 80,000 psi-increased to a constant.	

WEAR CHARACTERISTICS OF AMS 4925 TITANIUM ON SAE 4130 STEEL COMPARED WITH A STANDARD



NOTES

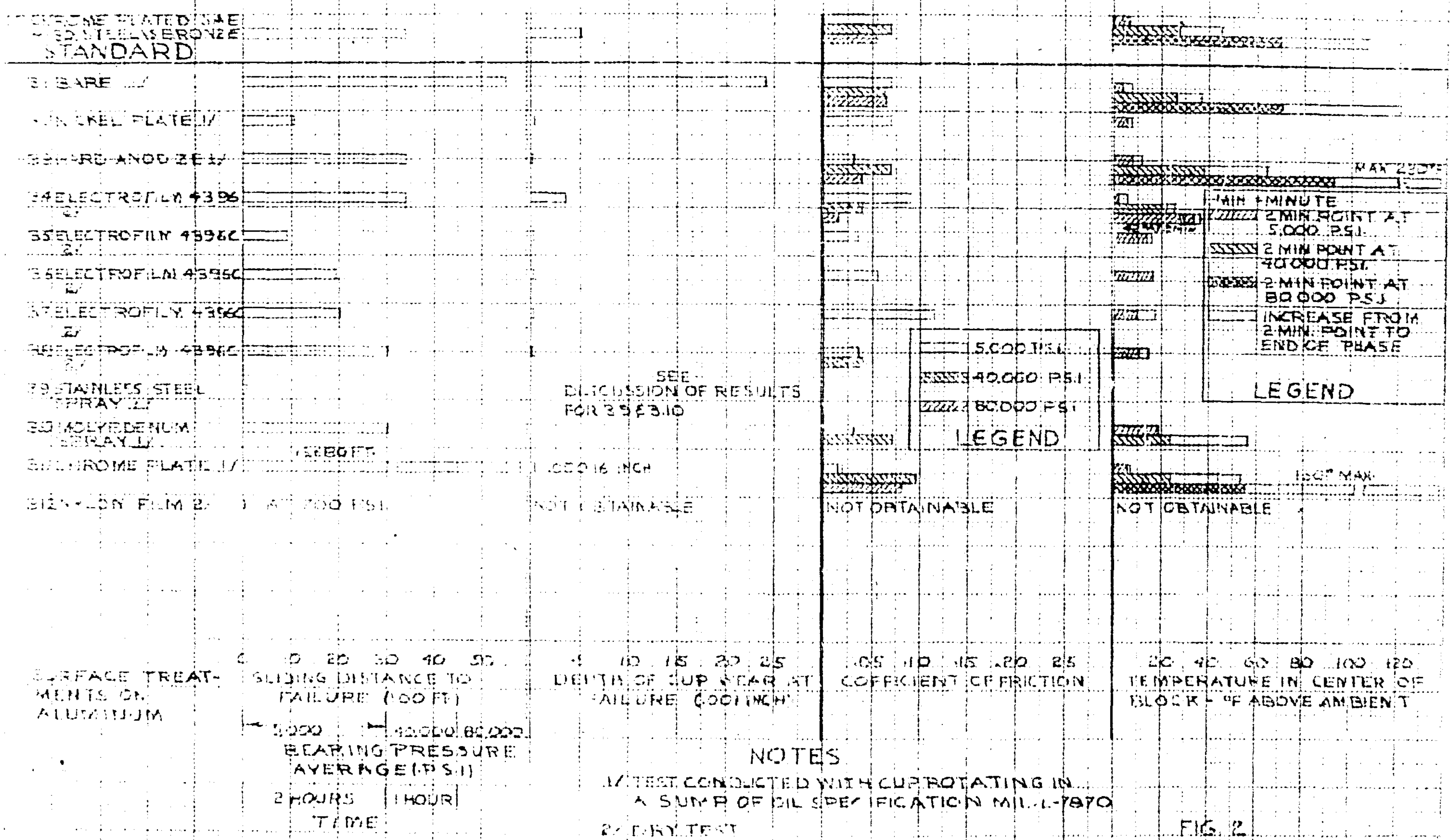
1/ TEST CONDUCTED WITH CUP ROTATING IN A SUMP OF OIL SPECIFICATION MIL-L-7870

2/ DRY TEST

SEE TABLE XII FOR DISCUSSION OF RESULTS

FIG 1

WEAR CHARACTERISTICS OF 7075-T6 ALUMINUM ON SAE 4130 STEEL COMPARED A STANDARD



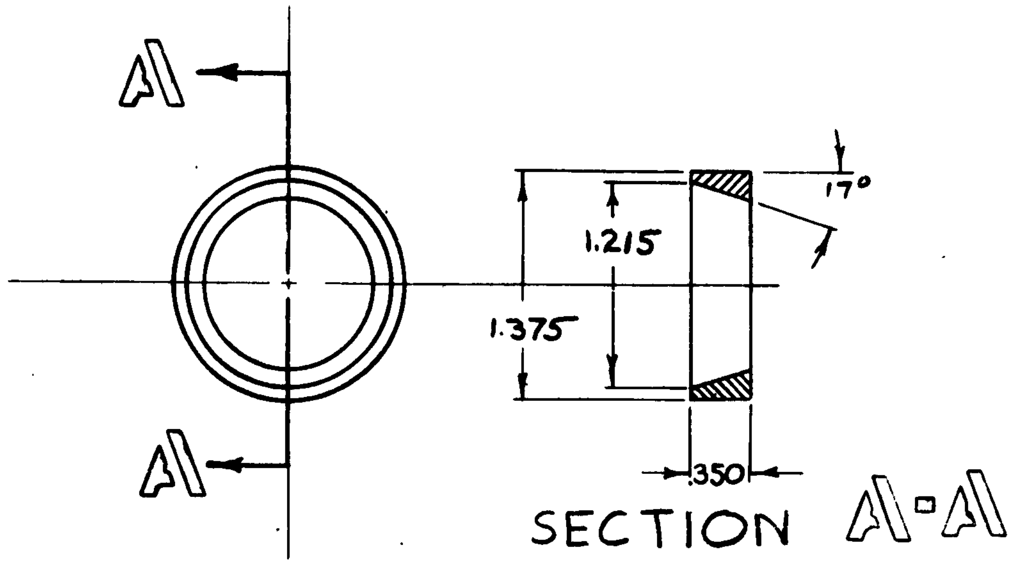
NOTES

1/ TEST CONDUCTED WITH CUP ROTATING IN A SUMP OF OIL SPECIFICATION MIL-L-7870

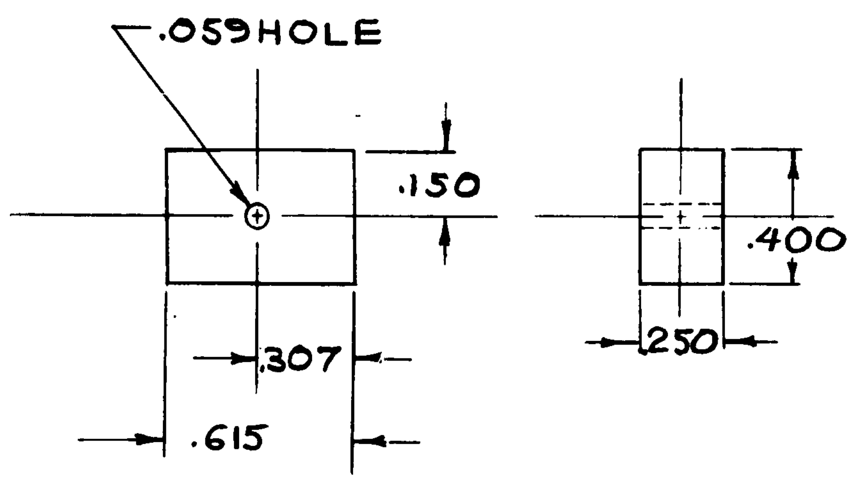
2/ DRY TEST

SEE TABLE XI FOR DISCUSSION OF RESULTS

FIG. 2



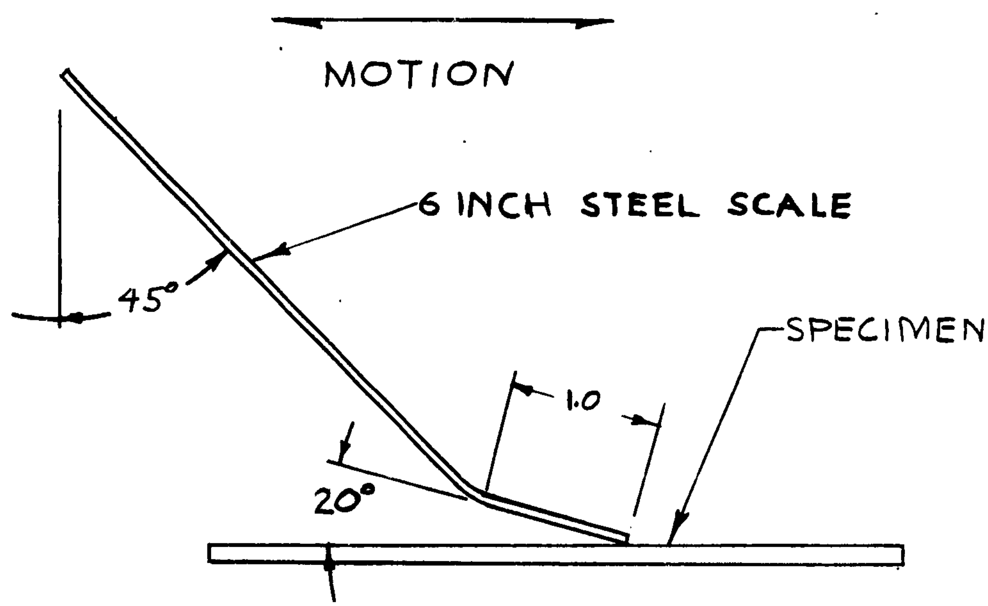
TIMKEN TEST CUP T-54148



TEST BLOCK

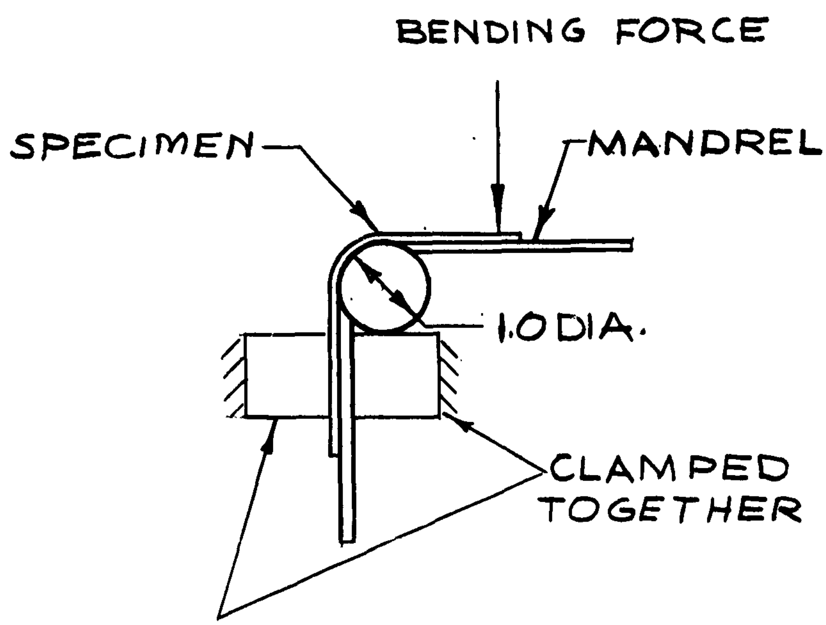
TEST CUP & BLOCK DIMENSIONS

FIG. 3



SCRAPE TEST

FIG. 4



BEND TEST

FIG 5

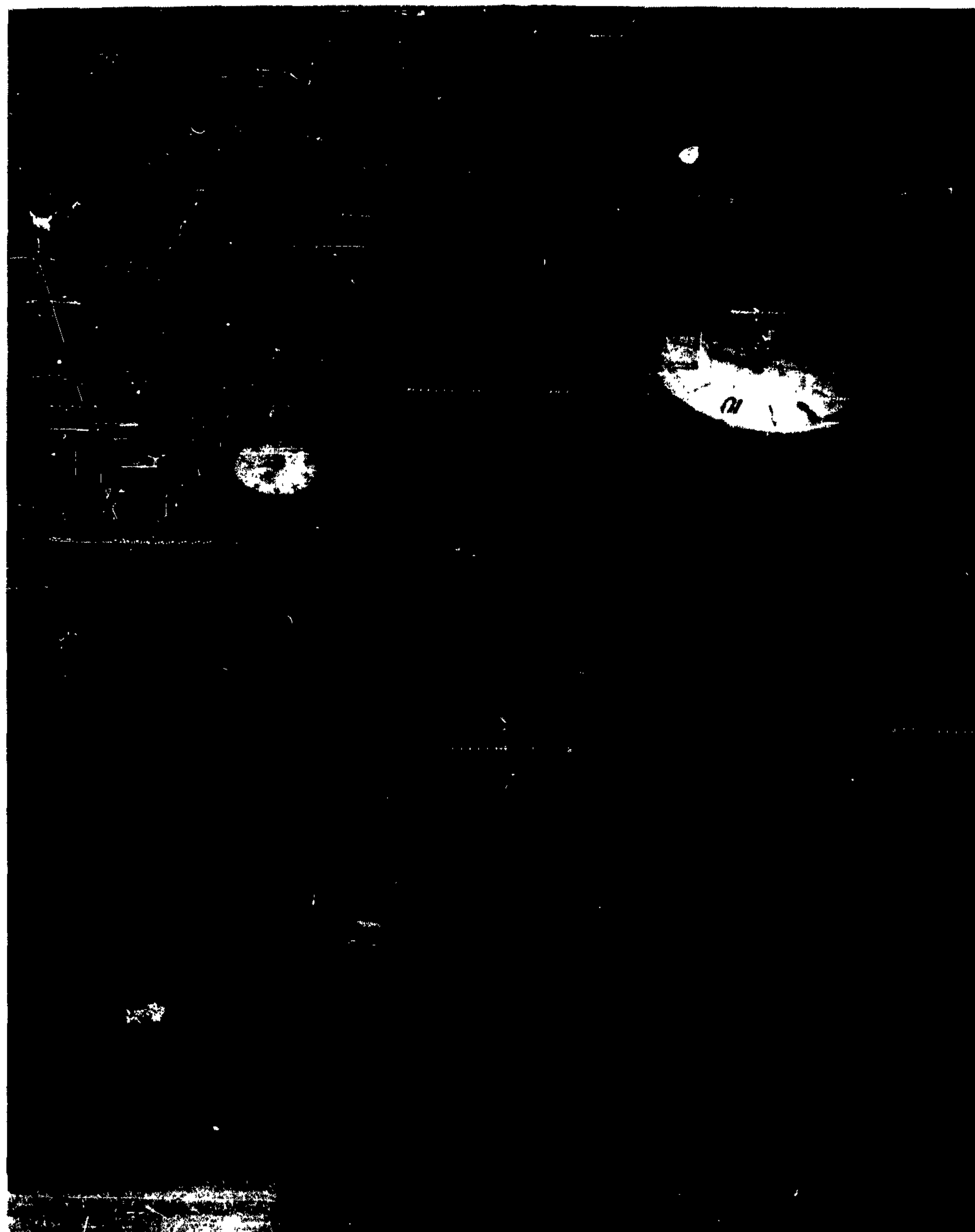


Figure 6 WEAR TEST MACHINE

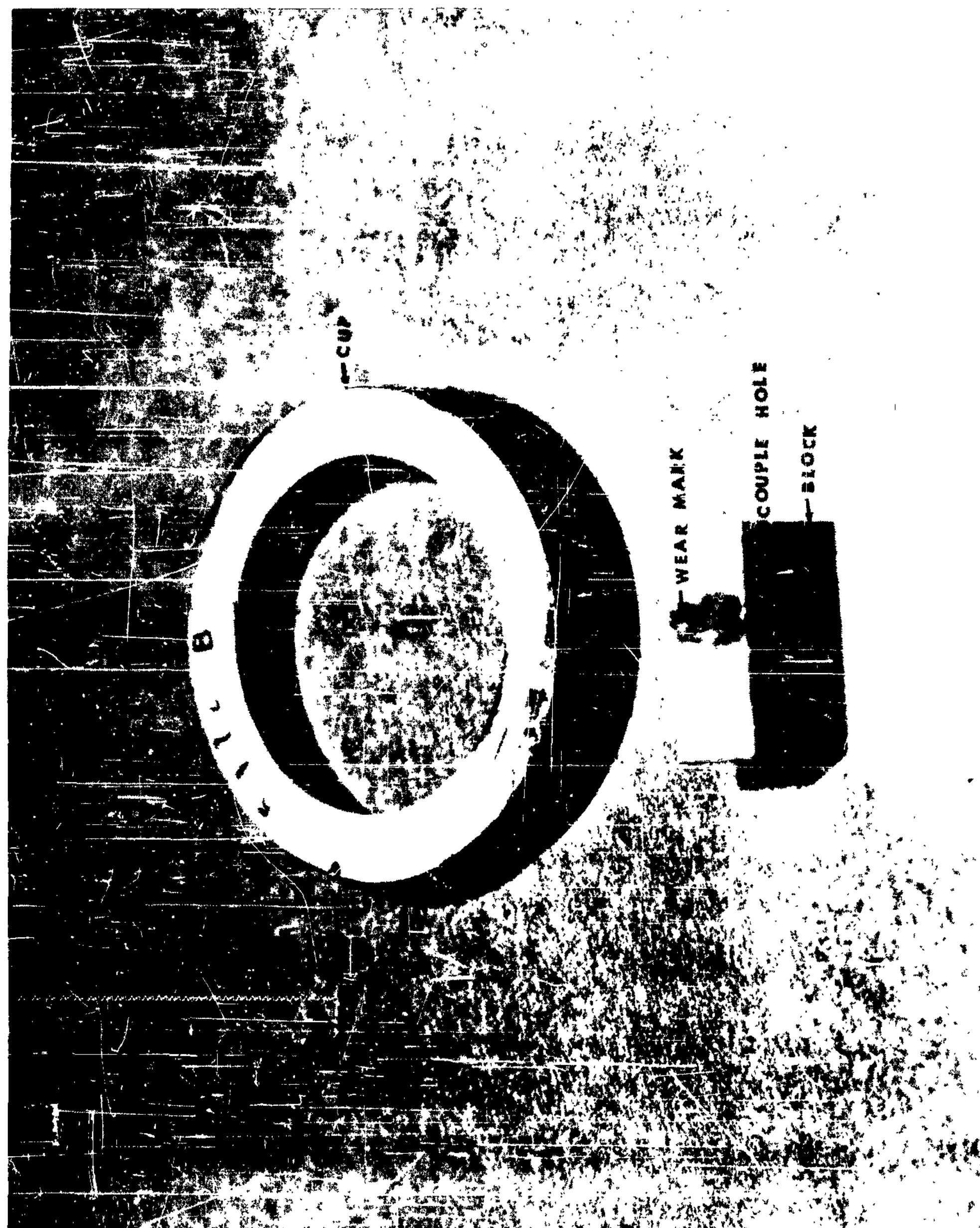


Figure 7 TYPICAL WEAR TEST CUP AND BLOCK

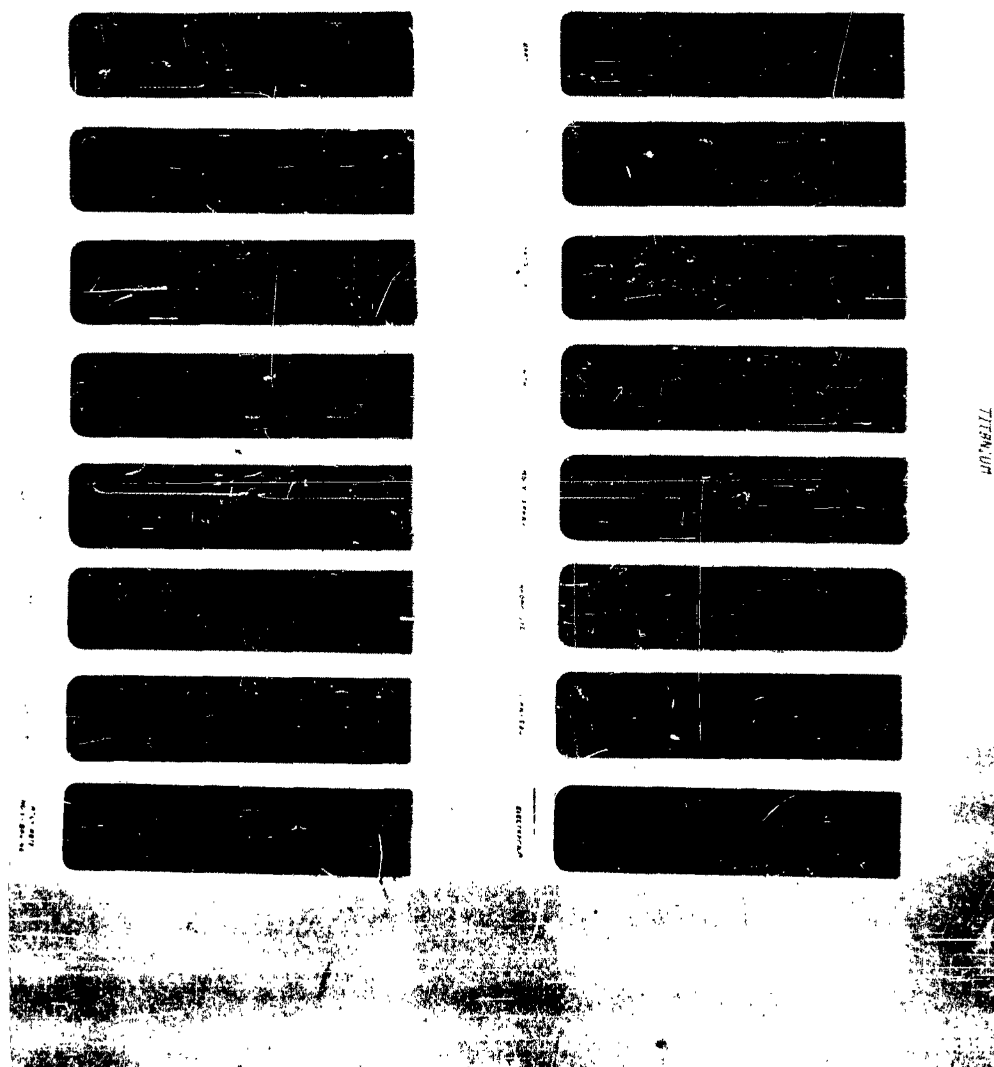


Figure 8 TITANIUM CORROSION SPECIMENS BEFORE EXPOSURE

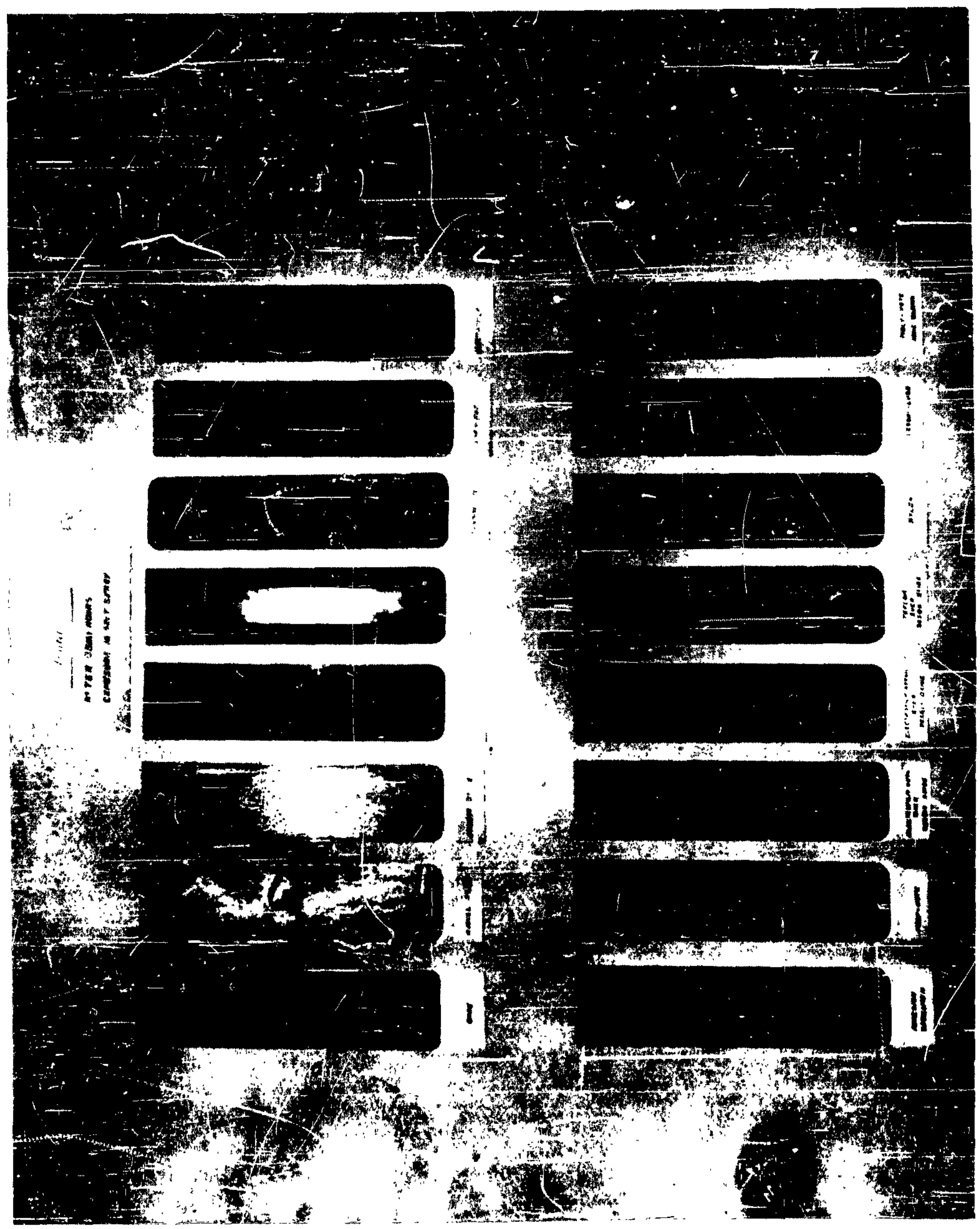


Figure 9 TITANIUM CORROSION SPECIMENS AFTER EXPOSURE

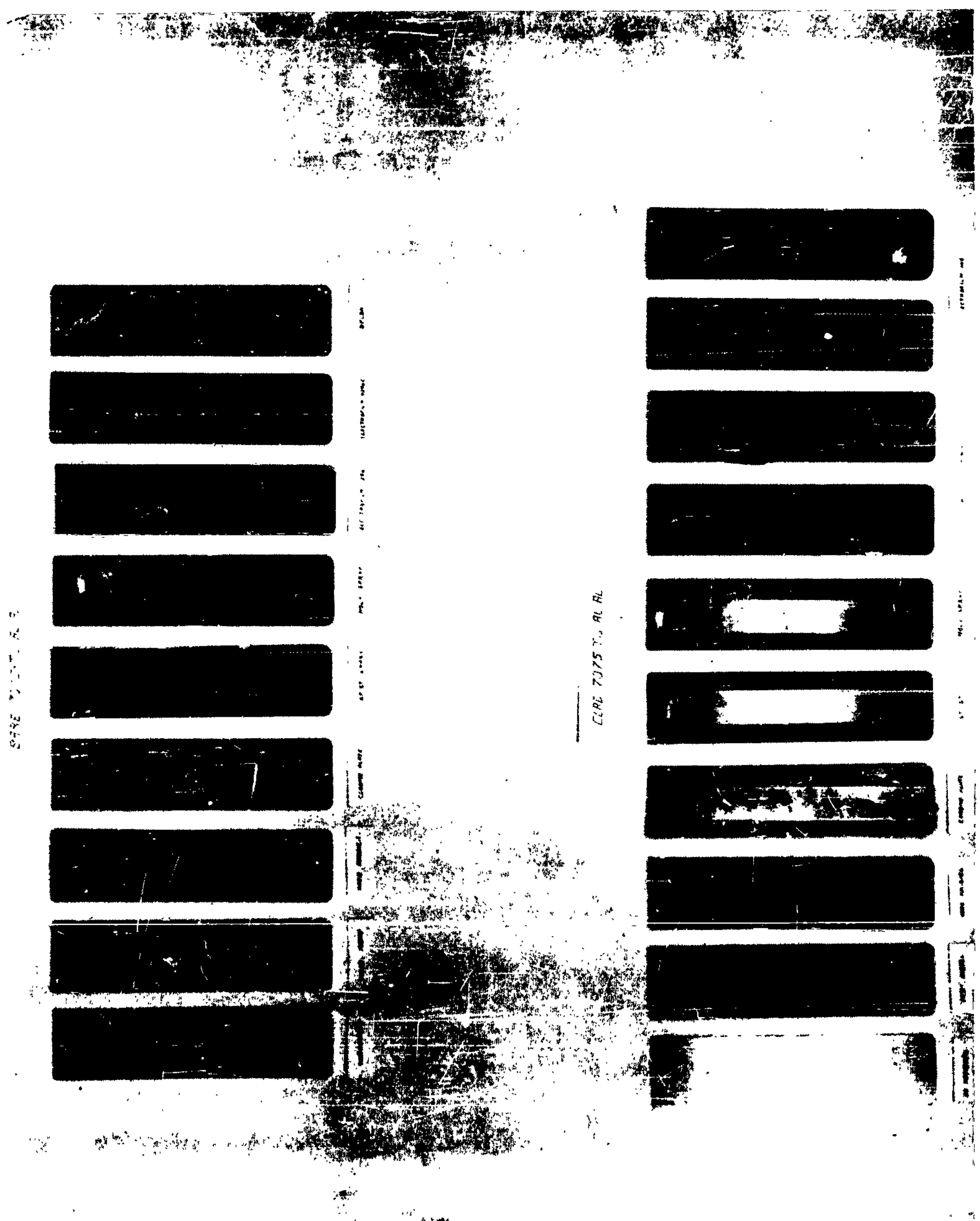


Figure 10 ALUMINUM CORROSION SPECIMENS BEFORE EXPOSURE

Figure 11 ALUMINUM CORROSION SPECIMENS AFTER EXPOSURE

STRUCTURES & MATERIALS LABORATORIES

CONVAIR

A DIVISION OF GENERAL DYNAMICS CORPORATION

SAN DIEGO

REPORT 56-64 Add I

DATE 19 March 1958

MODEL A11

Test No. 57-909

TITLE

REPORT NO. 56-64 ADDENDUM I
WEAR TEST OF ANODIC TREATMENT ON TITANIUM
MODEL A11

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NO. OF PAGES 3

NO. OF DIAGRAMS 1

REVISIONS

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REPORT NO. 56-64 ADDENDUM I
WEAR TEST OF ANODIC TREATMENT ON TITANIUM
MODEL ALL

INTRODUCTION:

This test was initiated to evaluate the quality of anodic treatment, on titanium, produced by a possible alternate process. Sesqui-oxide process is the present anodic treatment. The Ti-oxide and Hardas processes were considered as a second source.

OBJECT:

To compare the wear characteristics of anodic surface treatment on titanium alloy with sesqui-oxide treatment.

CONCLUSIONS:

The Hardas and the Ti-oxide processes were both superior to the sesqui-oxide process for properties tested. (no corrosion or adhesion tests were made.) See Figure 1 for graphic presentation of wear characteristics.

TEST SPECIMENS:

The same type of test specimens were used as described in the basic report. The test cups were machined from AMS 4925 titanium alloy, after which the following anodic treatments were applied.

2.16 and 2.17	Ti-oxide process, on surface of 16 RMS finish, by San Diego Plating Company, San Diego, Calif.
2.18	Sesqui-oxide, on surface of 16 RMS finish, by Chem-Tronics Laboratory, San Diego, Calif.
2.19 and 2.20	Hardas Process, on surface of 16 RMS finish, by Anachrome Corporation, South Gate, Calif.

TEST PROCEDURE:

The same test procedure was used as described on page 4 and 5 of the basic report. No corrosion or adhesion test were made.

RESULTS:

Anodic treatments of titanium surfaces have greater wear and anti-galling resistance then untreated surfaces. The results are shown in graphic form in Figure 1. Each bar in Figure 1 shows data which was obtained from one test specimen. For description of failure see page 5 of the original report.

Depth of wear for the sesqui-oxide treated test specimen was not measureable by conventional methods. Titanium particles adhered to the steel block immediately after the surface treatment was worn away. Although the cup wear was small, the friction doubled at failure.

The oil lubricated test cups showed less severe wear than the unlubricated test cups. Test cup 2.19 was slightly convex with two specks in the center of the wear surface. The specks were formed by the absence of coating at these points. Wear was first observed on test cup 2.19 by the appearance of a concentric band approximately 1/64 inch wide passing through the specks. This wear surface resulted in an increase in the actual bearing pressure. The actual amount of surface wear was negligible. The welding to the steel block was slight for this test cup.

A dry test cup 2.20 with a Hardas process treated surface, produced good wear resistance at 5,000 psi bearing pressure. Actual contact area on the Hardas process coating became black and polished after 5 minutes of rubbing time. Sufficient boundary lubrication was provided by the coating of test cup 2.20 when subjected to 5,000 psi bearing pressure. Failure occurred within a few revolutions of the test cup when 40,000 psi bearing pressure was applied. The parent material failed under the coating.

None of the anodic treated titanium surfaces rubbing on lubricated chrome molybdenum steel compared favorably to the bronze standard as a friction bearing material combination.

NOTE:

The test data from which this report was prepared are recorded in Structures Test Laboratory Data Book No. 393, pages 119 to 123.

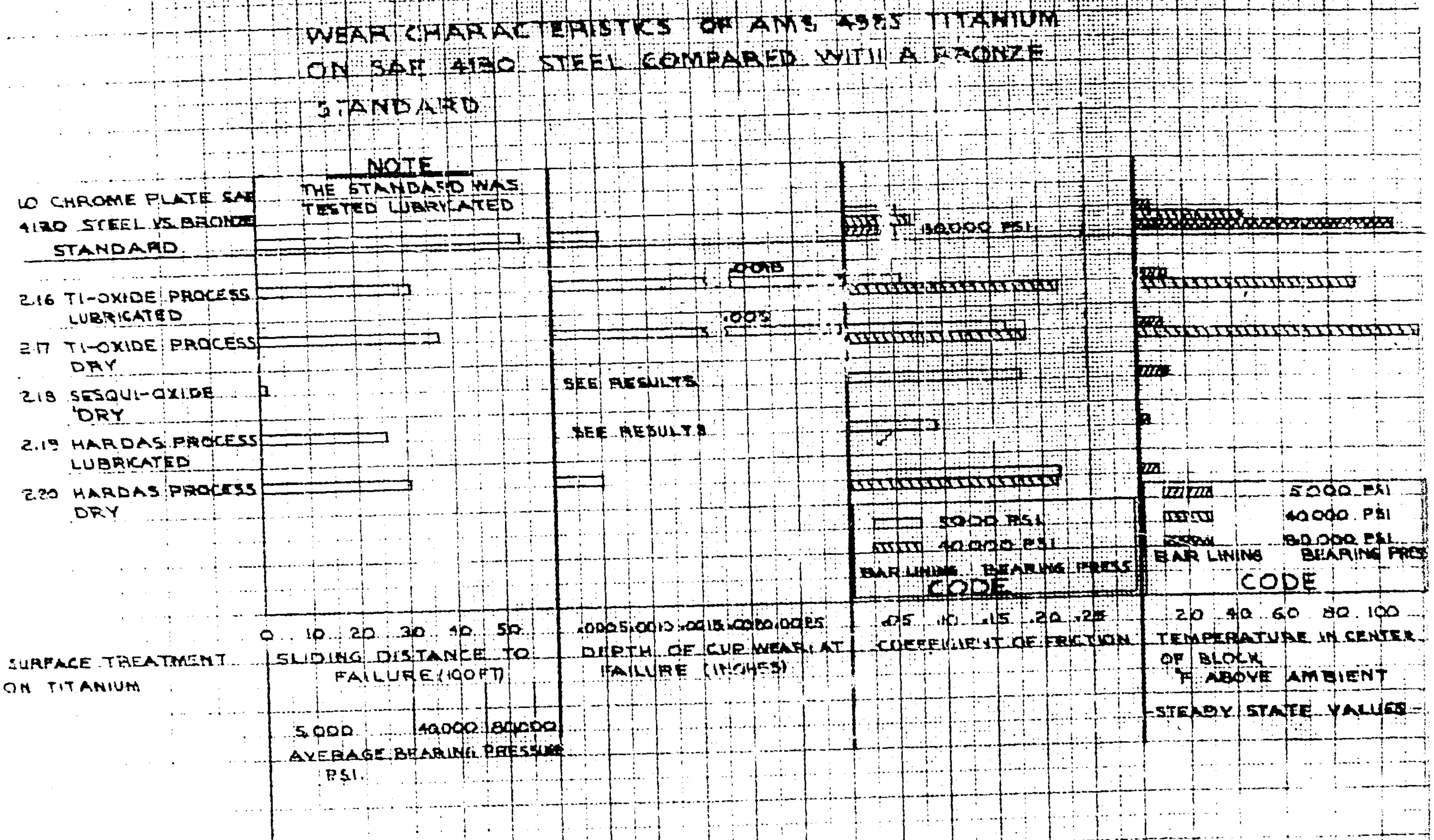
WEAR CHARACTERISTICS OF AMS 4952 TITANIUM
ON SAE 4130 STEEL COMPARED WITH A BRONZE
STANDARD
NOTE
THE STANDARD WAS TESTED LUBRICATED
10 CHROME PLATE SAE 4130 STEEL VS. BRONZE
STANDARD
2.16 TI-OXIDE PROCESS LUBRICATED
2.17 TI-OXIDE PROCESS DRY
2.18 SESQUI-OXIDE DRY
2.19 HARDAS PROCESS LUBRICATED
2.20 HARDAS PROCESS DRY
SURFACE TREATMENT ON TITANIUM
0 10 20 30 40 50
SLIDING DISTANCE TO FAILURE (100 FT)
5,000 40,000 80,000
AVERAGE BEARING PRESSURE PSI.
SEE RESULTS
SEE RESULTS
.0005 .0010 .0015 .0020 .0025
DEPTH OF CUP WEAR AT FAILURE (INCHES)
.005
.005
80,000 PSI
5000 PSI
40,000 PSI
BAR LINING BEARING PRESS
CODE
.05 .10 .15 .20 .25
COEFFICIENT OF FRICTION
5000 PSI
40,000 PSI
80,000 PSI
BAR LINING BEARING PRES
CODE
20 40 60 80 100
TEMPERATURE IN CENTER OF BLOCK
°F ABOVE AMBIENT
STEADY STATE VALUES

FIGURE I